CLAIMS

1. A force sensor for sensing a touch force applied to a touch surface, the force sensor comprising:

a first element including an elastic element and a first capacitor plate having a first capacitive surface, the elastic element including at least part of the first capacitor plate; and

a second element including a second capacitor plate opposed to the first capacitor plate;

wherein transmission of at least part of the touch force through the elastic element contributes to a change in capacitance between the first capacitor plate and the second capacitor plate.

2. The force sensor of claim 1, wherein the first element is substantially planar.

3. The force sensor of claim 1, wherein the first capacitor plate and the elastic element are integral.

4. The force sensor of claim 3, wherein the first capacitor plate and the elastic element are composed of the same substrate.

5. The force sensor of claim 3, wherein the elastic element comprises an elevated feature of the first capacitor plate.

6. The force sensor of claim 5, wherein the elevated feature is located at the elastic center of the first element.

7. The force sensor of claim 1, further comprising force-receiving means for receiving at least part of the touch force into the first element.

8. The force sensor of claim 7, wherein the force-receiving means comprises the elastic element.

9. The force sensor of claim 7, wherein the force-receiving means comprises a feature formed into the first element.

10. The force sensor of claim 9, wherein the force-receiving means comprises an elevated feature of the first capacitor plate.

11. The force sensor of claim 7, wherein the touch surface is in communication with a region of a surface of the force-receiving means, and wherein the touch surface tends to remain in contact with the region of the surface of the force-receiving means when the position of the touch surface changes with respect to the force-receiving means.

12. The force sensor of claim 1, further comprising force transmission means for transmitting at least part of the touch force to at least one structure other than the first element.

13. The force sensor of claim 1:

wherein the second element comprises a planar support surface that includes a plurality of electrically conductive mechanical bearing contacts;

and wherein at least portions of the first capacitor plate are in contact with the plurality of mechanical bearing contacts to transmit force thereto.

14. The force sensor of claim 13, wherein the second capacitor plate includes a second capacitive surface that is coplanar with the plurality of mechanical bearing contacts.

15. The force sensor of claim 14, wherein the second capacitive surface and the plurality of mechanical bearing contacts are composed of the same substrate.

16. The force sensor of claim 13, wherein the planar support surface is part of an interconnect system to transmit a signal developed in response to the change in capacitance between the first capacitor plate and the second capacitor plate.

17. The force sensor of claim 1, wherein the first and second capacitor plates are separated by a volume, and wherein the ratio of the height of the volume to the volume's greatest breadth is less than .05.

18. The force sensor of claim 1, further comprising:

force signal development means for developing a signal in response to the change in capacitance between the first capacitor plate and the second capacitor plate.

19. The force sensor of claim 1, wherein the force sensor includes an axis of sensitivity that passes through the elastic center of the elastic element.

20. The force sensor of claim 1, further comprising:

the touch surface, wherein the touch surface is a touch surface of a handheld device.

21. The force sensor of claim 1, wherein the second capacitor plate is separated by a capacitive gap from the first capacitor plate, the length of the mechanical path defining the capacitive gap being no greater than one-fifth of the maximum distance between any two force sensors that are used in the touch location device to measure the touch force.

22. A force sensor for sensing a touch force applied to a touch surface, the force sensor comprising:

a first substantially planar element comprising:

a first capacitor plate having a first capacitive surface; and

an elastic element comprising an integral elevated feature of the first capacitor plate, the elastic element receiving at least part of the touch force into the first element; and

a second element including a second capacitor plate opposed to the first capacitor plate;

wherein transmission of at least part of the touch force through the elastic element contributes to a change in capacitance between the first capacitor plate and the second capacitor plate.

23. A force sensor for sensing a touch force applied to a touch surface, the force sensor comprising:

a first element including an elastic element and a first capacitor plate including a first capacitive surface, the elastic element and the first capacitive surface being substantially coplanar;

a second element including a second capacitor plate;

wherein transmission of at least part of the touch force through the elastic element contributes to a change in capacitance between the first capacitor plate and the second capacitor plate.

24. The force sensor of claim 23, wherein the first capacitor plate and the elastic element are integral.

25. The force sensor of claim 23, wherein the elastic element is produced by forming an elevated feature into the first capacitor plate.

26. The force sensor of claim 23, wherein the first and second capacitor plates are separated by a volume, the ratio of the height of the volume to the volume's greatest breadth being less than .05.

27. A force sensor for sensing a touch force applied to a touch surface, the force sensor comprising:

a first element including an elastic element, a first capacitor plate including a first capacitive surface, force-receiving means for receiving at least part of the touch force into the first element, force-transmitting means for transmitting at least part of the touch force to structures not including the first element;

a second element including a second capacitor plate; and

wherein transmission of at least part of the touch force through the elastic element contributes to a change in capacitance between the first capacitor plate and the second capacitor plate; and

wherein the smallest rectangular parallelepiped that encloses the first capacitive surface, the elastic element, and the second capacitor plate has a greatest dimension that is at least five times its least dimension.

28. The force sensor of claim 27, wherein the elastic element comprises the force-receiving means.

29. The force sensor of claim 27, wherein the elastic element and the first capacitor plate are integral.

30. The force sensor of claim 27, wherein the second element comprises a planar support surface that includes a plurality of electrically conductive mechanical bearing contacts;

wherein the second capacitor plate includes a second capacitive surface that is coplanar with the plurality of mechanical bearing contacts; and

wherein at least portions of the first capacitor plate are in contact with the plurality of mechanical bearing contacts to transmit force thereto.

31. The force sensor of claim 30, wherein the planar support surface is part of an interconnect system to transmit a signal developed in response to the change in capacitance between the first capacitor plate and the second capacitor plate.

32. A force sensor for sensing a touch force applied to a touch surface, the force sensor comprising:

a first element including a first capacitor plate including a first capacitive surface;

a second element including a second capacitor plate having a second capacitive surface, at least a portion of the first element being in contact with at least one support region of the second element to transmit force thereto, the second capacitive surface being substantially coplanar with the at least one support region; and

wherein transmission of at least part of the touch force to the first element contributes to a change in capacitance between the first capacitor plate and the second capacitor plate.

33. The force sensor of claim 32, wherein the at least one support region is part of an interconnect system to transmit a signal developed in response to the change in capacitance between the first capacitor plate and the second capacitor plate.

34. A force sensor for sensing a touch force applied to a touch surface, the force sensor comprising:

a first element including a first capacitor plate including a first capacitive surface;

a second element including a second capacitor plate, the second element being part of an interconnect system to transmit a signal developed in response to the change in capacitance between the first capacitor plate and the second capacitor plate, at least a portion of the first element being in contact with at least one support region of the second element to transmit force thereto;

wherein transmission of at least part of the touch force to the first element contributes to a change in capacitance between the first capacitor plate and the second capacitor plate.

35. The force sensor of claim 34, wherein the second capacitive surface and the at least one support surface are integral.

36. A force sensor for sensing a touch force applied to a touch surface, the force sensor comprising:

a first element including a first capacitor plate including a first capacitive surface;

a second element including a second capacitor plate separated by a capacitive gap from the first capacitor plate, the length of the mechanical path defining the capacitive gap being no greater than four times the maximum dimension of the volume of the capacitive gap;

wherein transmission of at least part of the touch force to the first element contributes to a change in capacitance between the first capacitor plate and the second capacitor plate.

37. The force sensor of claim 36, wherein the second capacitor plate is separated from the first capacitor plate in the unloaded state of the force sensor by not more than 10 mils.

38. A force sensor for sensing a touch force applied to a touch surface, the force sensor comprising:

a first element including a first capacitor plate including a first capacitive surface;

a second element including a second capacitor plate separated by a capacitive gap from the first capacitor plate, the aggregate normal component of the mechanical path defining the capacitive gap being no greater than twice the size of the capacitive gap;

wherein transmission of at least part of the touch force to the first element contributes to a change in capacitance between the first capacitor plate and the second capacitor plate.

39. The force sensor of claim 38, wherein the average width of the capacitive gap in an unloaded state of the force sensor is not less than thirty times the average height of the capacitive gap in the unloaded state of the force sensor.

40. A force sensor for sensing a touch force applied to a touch surface, the force sensor comprising:

a first element including force-receiving means for receiving at least part of the touch force into the first element and a first capacitor plate including a first capacitive surface;

a second element including a second capacitor plate separated by a capacitive gap from the first capacitor plate, wherein the average width of the capacitive gap in an unloaded state of the force sensor is not less than thirty times the average height of the capacitive gap in the unloaded state of the force sensor;

wherein transmission of at least part of the touch force to the first element contributes to a change in capacitance between the first capacitor plate and the second capacitor plate.

41. A force sensor for sensing a touch force applied to a touch surface, the force sensor comprising:

a first element including an elastic element, and a first capacitor plate including a first capacitive surface; and

a second element including a second capacitor plate;

wherein transmission of at least part of the touch force through the elastic element contributes to a change in capacitance between the first capacitor plate and the second capacitor plate; and

wherein the force sensor has a normal stiffness not less than 0.5 pounds per mil.

42. A force sensing touch location device comprising:

a touch surface;

a bezel enclosing a first portion of the touch surface; and

force transmission means including an enclosing portion enclosing a second portion of the touch surface, said force transmission means having a stiffness greater than that of the bezel, wherein the force transmission means includes a path to transmit force from the bezel to a region not including the touch surface.

43. The force sensing touch location device of claim 42, wherein the region comprises a stiff surface.

44. The force sensing touch location device of claim 43, wherein the touch surface is disposed between the bezel and the stiff surface.

45. The force sensing touch location device of claim 42, wherein the portion enclosing the touch surface is narrow.

46. The force sensing touch location device of claim 45, wherein the force transmission means comprises at least one thin rigid leg in contact with the bezel and the region not including the touch surface.

47. The force sensing touch location device of claim 42, wherein a flange of the force transmission means encloses the second portion of the touch surface.

48. The force sensing touch location device of claim 42, wherein the force comprises a force that is perpendicular to the touch surface.

49. The force sensing touch location device of claim 42, wherein the path comprises a frame surrounding the touch surface.

50. The force sensing touch location device of claim 49, wherein the frame comprises the force transmission means.

51. The force sensing touch location device of claim 43, wherein the stiff surface comprises a surface of a display device.

52. The force sensing touch location device of claim 51, wherein the display surface comprises an LCD device surface.

53. The device of claim 42, wherein said force transmission means provides attachment for a vertically compliant seal between said bezel and said touch surface.

54. The device of claim 53, further comprising the vertically compliant seal.

55. The device of claim 53, wherein the attachment comprises a flange of the force transmission means.

56. The force sensing touch location device of claim 53, wherein the force transmission means comprises a rigid flange coupled to the bezel.

57. The force sensing touch location device of claim 54, wherein the force transmission means provides a bearing region to receive perpendicular forces establishing an additional seal between said force transmission means and the bezel, said bezel perpendicularly overlying at least a line of junction of said vertically compliant seal and said force transmission means.

58. The device of claim 49, wherein said frame provides attachment for a lateral stiffening means between said frame and said touch surface.

59. The device of claim 49, wherein said frame provides an attachment for receiving both a vertically compliant seal and a lateral stiffening means.

60. The device of claim 59, wherein the seal and the lateral stiffening means are the same element.

61. The device of claim 59, wherein the attachment comprises a rigid bearing edge.

62. The device of claim 49, wherein the frame includes an attachment for receiving both the vertically compliant seal and a surface of the bezel that acts as a second seal.

63. The device of claim 42, wherein the bezel includes an alignment feature for aligning the touch surface within the enclosure.

64. The force sensing touch location device of claim 42, wherein the narrow portion closely invests, but does not touch, the touch display surface around the periphery of the touch display.

65. The force sensing touch location device of claim 42, further comprising:

a handheld computing device including the touch surface, the bezel, and the force transmission means.

66. A force sensing touch location device comprising:

a touch surface;

a bezel enclosing a first portion of the touch surface; and

force transmission means including an enclosing portion enclosing a second portion of the touch surface and at least one thin rigid leg in contact with the bezel and a stiff surface not including the touch surface, said force transmission means having a stiffness greater than that of the bezel, wherein the force transmission means includes a path to transmit force from the bezel to the stiff surface not including the touch surface.

67. A force sensing touch location device comprising:

a touch surface defining a touch plane;

a first rigid member;

a contoured first film coupled to the touch surface and the first rigid member to form a first seal therebetween, the contoured first film being compliant along an axis normal to the touch plane.

68. The force sensing touch location device of claim 67, wherein said contoured first film contacts a second rigid member and wherein said contoured first film is disposed between the second rigid member and the first rigid member to form a second seal between the contoured first film and the second rigid member.

69. The force sensing touch location device of claim 68, wherein the second rigid member contacts said contoured first film over a portion of said first rigid member.

70. The force sensing touch location device of claim 68, wherein the first seal comprises a seal between the touch surface and a surrounding frame.

71. The force sensing touch location device of claim 70, wherein the first rigid member comprises a portion of the frame.

72. The force sensing touch location device of claim 71, wherein the second seal comprises a seal between the frame and a bezel enclosing the touch surface, and wherein the first rigid member receives perpendicular forces from the bezel to establish the second seal, a portion of said bezel overlying a line of junction of said first seal and said frame.

73. The force sensing touch location device of claim 71, wherein the contoured first film includes a bulge between the touch surface and the frame, and wherein the bulge is compliant along the axis normal to the touch plane.

74. The force sensing touch location device of claim 70, wherein the second seal comprises:

a bezel including a slot;

an insert removably engaged in the slot; and

a second film covering at least a portion of the force sensing touch surface.

75. The force sensing touch location device of claim 67, wherein the contoured first film is transparent.

76. The force sensing touch location device of claim 75, wherein the contoured first film comprises a transparent film having a portion overlaying at least part of the touch surface.

77. The force sensing touch location device of claim 76, wherein the transparent film overlays the entire touch surface.

78. The force sensing touch location device of claim 71, wherein a portion of the contoured first film extends from the rigid supporting member to the touch surface, whereby a gap is formed between the portion of the contoured first film and a portion of the touch surface.

79. The force sensing touch location device of claim 67, wherein a portion of the contoured first film extends from the rigid supporting member to the touch surface in a direction not parallel to the touch plane.

80. The force sensing touch location device of claim 67, wherein the contoured first film and the touch surface comprise a monolithic element.

81. A method for measuring the touch force applied to the touch surface using the force sensor of claim 1, the method comprising a step of:

(A) developing a signal based on the change in capacitance between the first capacitor plate and the second capacitor plate.

82. The method of claim 81, wherein the amplitude of the signal is a monotonic function of the change in capacitance between the first capacitor plate and the second capacitor plate.

83. The method of claim 81, further comprising a step of:

(B) measuring a property of the touch force based on the signal.

84. The method of claim 83, wherein the step (B) comprises a step of measuring the amplitude of a component of the touch force that is perpendicular to the touch surface.

85. The method of claim 83, wherein the step (B) comprises a step of measuring a location on the touch surface at which the touch force is applied.

86. In a force sensor, a method for separating a first capacitor plate from a second capacitor plate by a desired volume, the method comprising steps of:

(A) disposing a separator between a support surface and a principal element including the first capacitor plate to maintain a separation of at least the desired volume between the first capacitor plate and the second capacitor plate;

(B) coupling at least one region of the principal element to at least one region of the support surface; and

(C) removing the separator, whereby the first capacitor plate and the second capacitor plate remain separated by at least the desired volume in an unloaded state of the force sensor.

87. The method of claim 86, wherein the support surface comprises the second capacitor plate.

88. The method of claim 86, wherein the support surface is part of an interconnect system to transmit a signal developed in response to the change in capacitance between the first capacitor plate and the second capacitor plate.

89. The method of claim 86, wherein the principal element and the at least one region of the support surface are substantially parallel.

90. The method of claim 86, wherein the at least one region of the principal element and the at least one region of the support surface are electrically conductive, and wherein the step (B) comprises a step of coupling the at least one region of the principal element to at least one region of the support surface with an electrically conductive substrate.

91. The method of claim 86, wherein the separator comprises a shim.

92. The method of claim 86, wherein the method further comprises a step of:

(D) prior to the step (B), selecting a substantially planar sheet of material as the principal element.

93. The method of claim 86, wherein the step (A) comprises disposing a predetermined substrate between the support surface and the principal element, and wherein the step (B) comprises a step of using the predetermined substrate to couple the at least one region of the principal element to the at least one region of the support surface.

94. In a force sensor, a method for separating a first capacitor plate from a second capacitor plate by a desired volume, the method comprising steps of:

(A) disposing a predetermined substrate containing particles of controlled size between a support surface and a principal element including the first capacitor plate to produce a separation of at least the desired volume between the first capacitor plate and the second capacitor plate; and

(B) coupling at least one region of the principal element to at least one region of the support surface to maintain the separation of at least the desired volume between the first capacitor plate and the second capacitor plate.

95. The method of claim 94, wherein the step (A) comprises a step of flowing the predetermined substrate in a fluid state between the principal element and the support surface, and wherein the step (B) comprises a step of allowing the predetermined substrate to transition into a solid state.

96. A method for manufacturing a force sensor, the method comprising steps of:

(A) selecting a principle element including a substantially flat surface and a first capacitive surface;

(B) disposing the first capacitive surface in opposition to a second capacitive surface; and

(C) forming an elevated elastic feature into the substantially flat surface, whereby transmission of a force through the elevated elastic feature contributes to a change in capacitance between the first capacitor plate and the second capacitor plate.

97. The method of claim 96, wherein the substantially flat surface and the first capacitive surface are integral.

98. The method of claim 96, wherein the step (A) comprises a step of selecting a sheet of electrically conductive material as the principal element.

99. The method of claim 96, further comprising a step of:

(D) placing the elevated elastic feature in communication with a touch surface to which the force is applied, whereby the elevated elastic feature provides a region of load transmission from the touch surface to the principal element.

100. In a force sensor, a method for separating a first capacitor plate from a second capacitor plate by a desired volume, the method comprising steps of:

(A) disposing a separator between the second capacitor plate and a substantially planar principal element including the first capacitor plate to maintain a separation of at least the desired volume between the first capacitor plate and the second capacitor plate;

(B) coupling at least one region of the principal element to at least one region of the support surface that is substantially parallel to the principal element; and

(C) removing the separator, whereby the first capacitor plate and the second capacitor plate remain separated by at least the desired volume in an unloaded state of the capacitive force sensor.

101. A force sensing touch location device comprising:

a touch surface structure to which a touch force may be applied, the touch force including a perpendicular component that is perpendicular to a touch surface of the touch surface structure and a tangential component that is tangential to the touch surface of the touch surface structure;

a supporting structure;

at least one force sensor, in communication with the touch surface and the supporting structure, to measure properties of the touch force;

lateral restraint means, in contact with both the touch surface structure and the supporting structure, for impeding lateral motion of the touch surface structure without substantially impeding transmission of the perpendicular component of the touch force through the at least one force sensor.

102. The force sensing touch location device of claim 101, wherein the lateral restraint means comprises a thin member in contact with both the touch surface structure and the supporting structure.

103. The force sensing touch location device of claim 102, wherein the thin member joins the touch surface to a surrounding frame.

104. The force sensing touch location device of claim 103, wherein the thin member comprises at least one strip of tape.

105. The force sensing touch location device of claim 102, wherein the thin member is constructed of high-modulus material to be substantially stiff to tangential movement of the touch surface and substantially compliant to perpendicular motion of the touch surface.

106. The force sensing touch location device of claim 101, wherein the touch surface comprises a display surface.

107. The force sensing touch location device of claim 101, wherein the touch surface comprises a touch overlay overlaying a display surface.

108. The force sensing touch location device of claim 101, wherein the lateral restraint means comprises a preload spring.

109. The force sensing touch location device of claim 108, wherein the preload spring is fastened to an edge of the touch surface.

110. The force sensing touch location device of claim 108, wherein the preload spring has a non-uniform unloaded curvature.